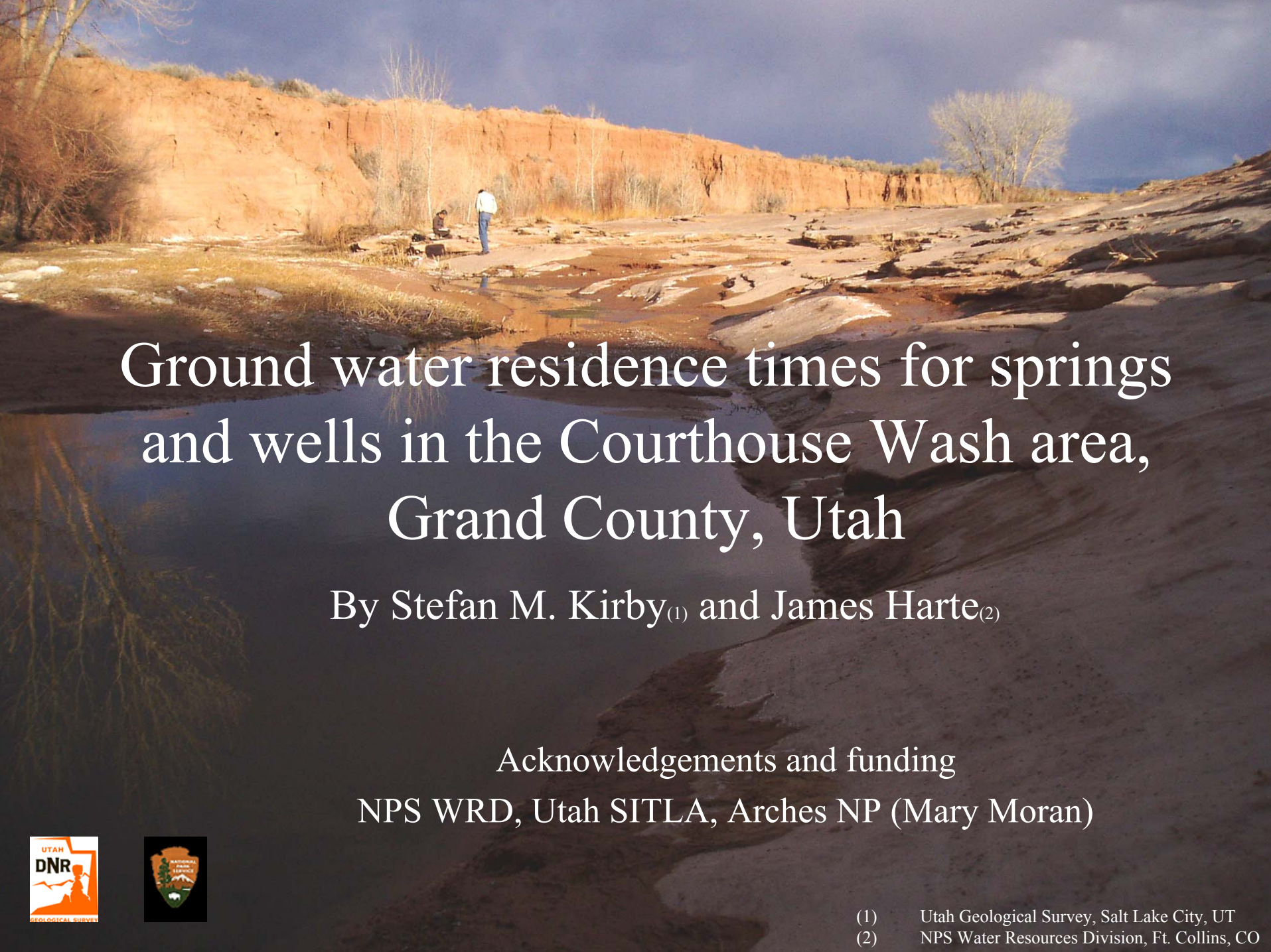


Ground water residence times for springs and wells in the Courthouse Wash area, Grand County, Utah

By Stefan M. Kirby(1) and James Harte(2)

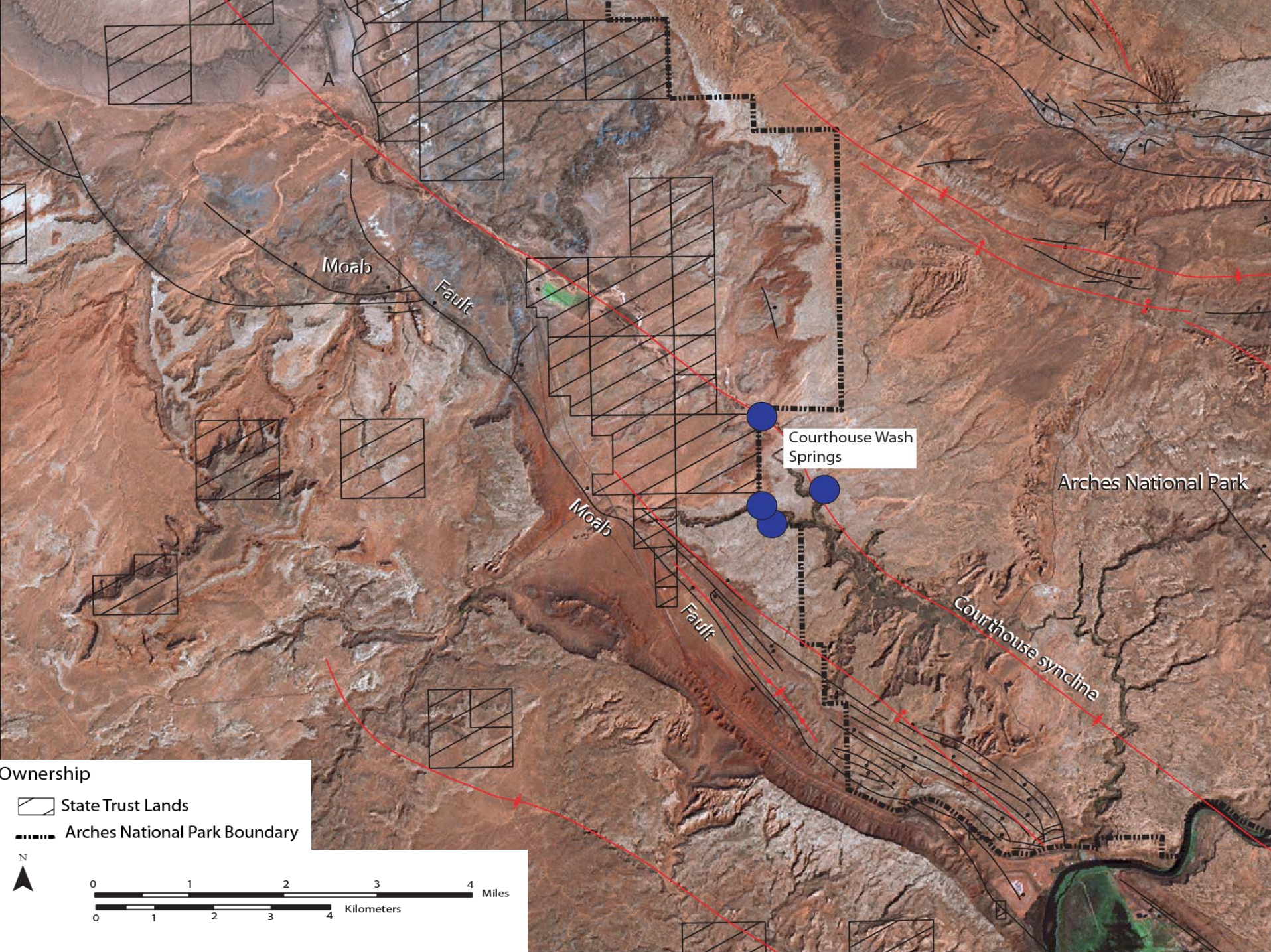
Acknowledgements and funding

NPS WRD, Utah SITLA, Arches NP (Mary Moran)

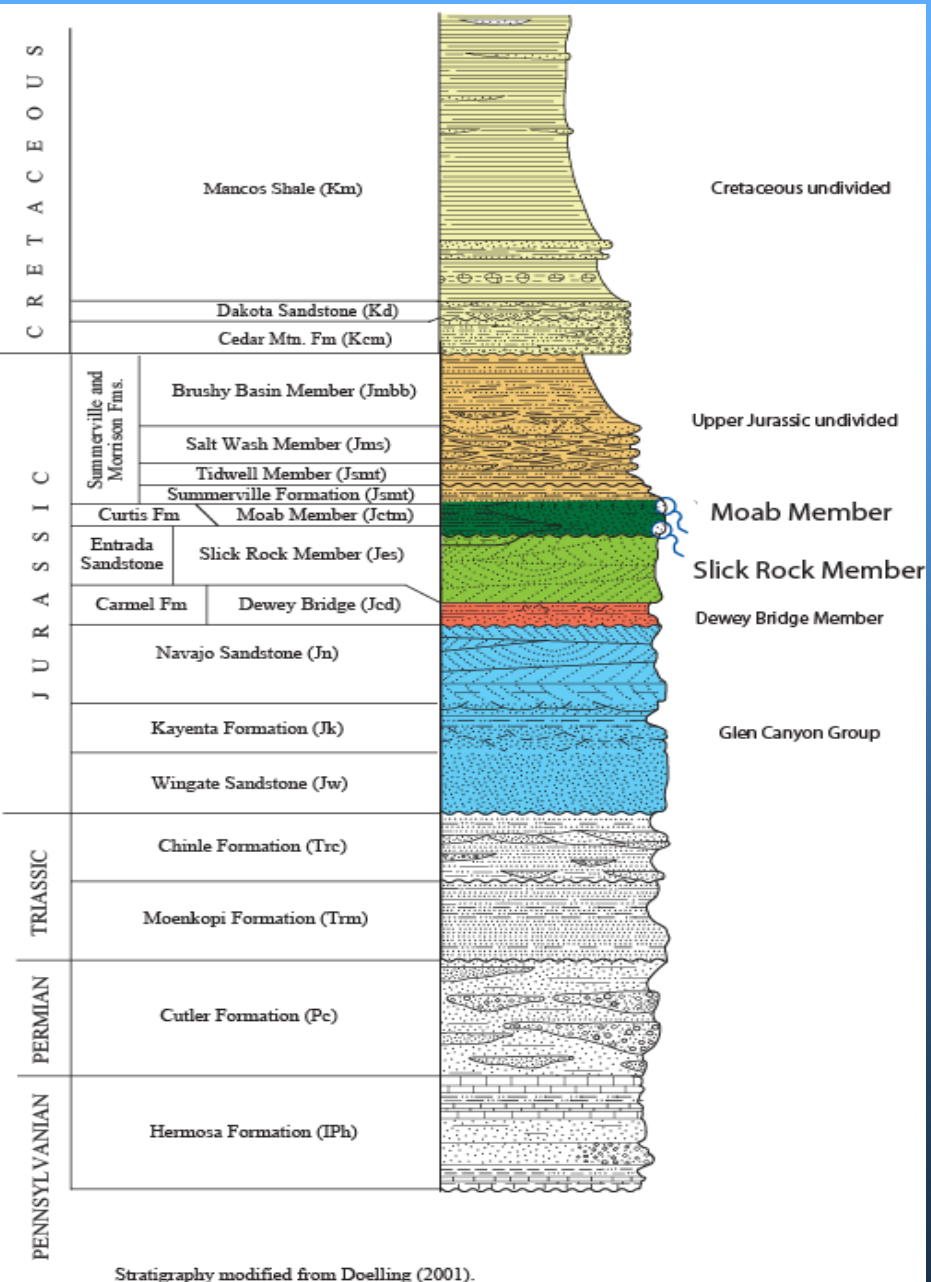
(1) Utah Geological Survey, Salt Lake City, UT
(2) NPS Water Resources Division, Ft. Collins, CO

Background

- Springs and seeps provide a section of important perennial flow along Courthouse Wash in Arches NP
- Potential for interference from future ground-water development outside of Arches?
- New sampling (funded by NPS WRD) undertaken to help define flow to springs

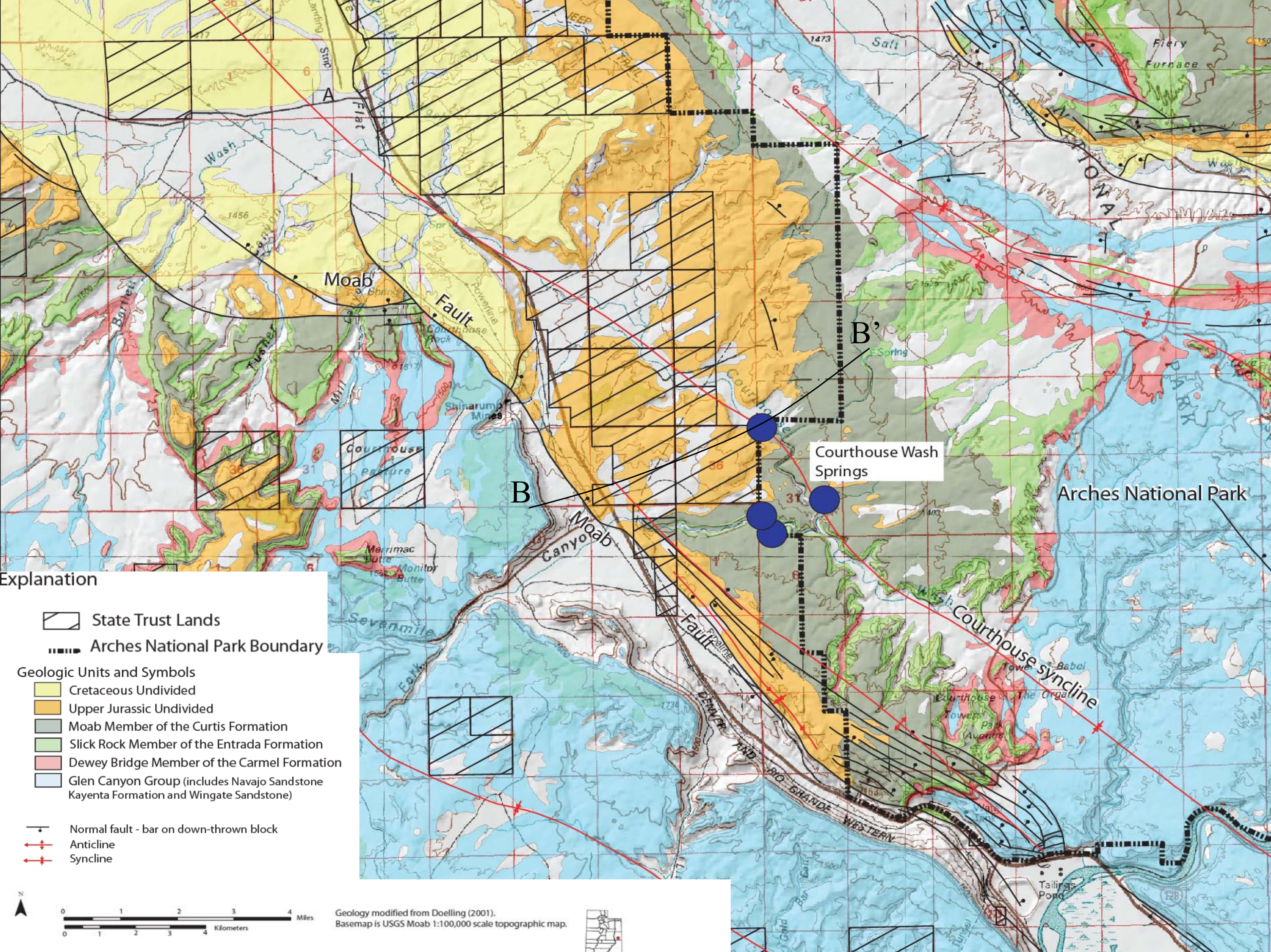

A
Moab
Fault
Courthouse Wash
Springs
Arches National Park
Moab
Fault
Courthouse syncline
Ownership
State Trust Lands
Arches National Park Boundary
N
0 1 2 3 4 Miles
0 1 2 3 4 Kilometers

Geologic Background



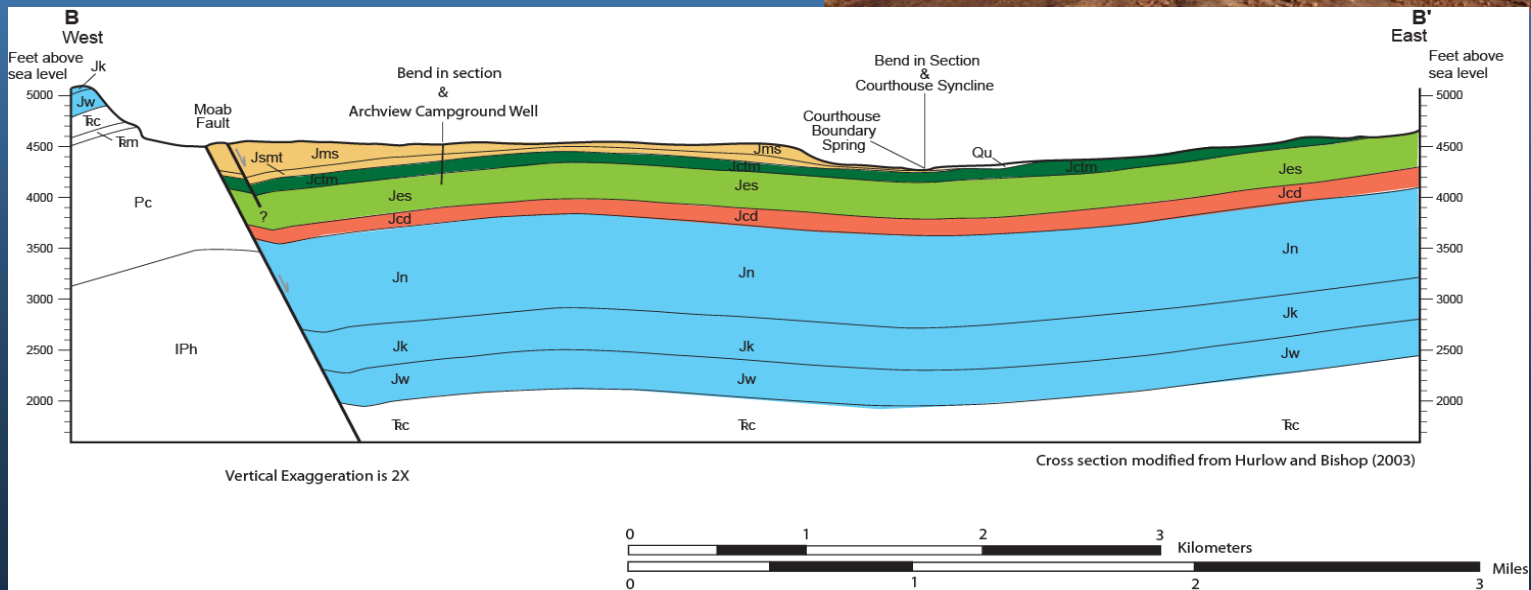
Stratigraphy modified from Doelling (2001).

- Jurassic units
- Eolian ss
- Important aquifers Jn, Jes, Jctm
- Overlying impermeable units
- Upper Jurassic and Cretaceous


Moab
Fault
Moab Canyon
Fault
Courthouse Wash Springs
Arches National Park
Courthouse syncline
B
B'
A
Explanation
State Trust Lands
Arches National Park Boundary
Geologic Units and Symbols
Cretaceous Undivided
Upper Jurassic Undivided
Moab Member of the Curtis Formation
Slick Rock Member of the Entrada Formation
Dewey Bridge Member of the Carmel Formation
Glen Canyon Group (includes Navajo Sandstone Kayenta Formation and Wingate Sandstone)
Normal fault - bar on down-thrown block
Anticline
Syncline
Miles
Kilometers
Geology modified from Doelling (2001).
Basemap is USGS Moab 1:100,000 scale topographic map.

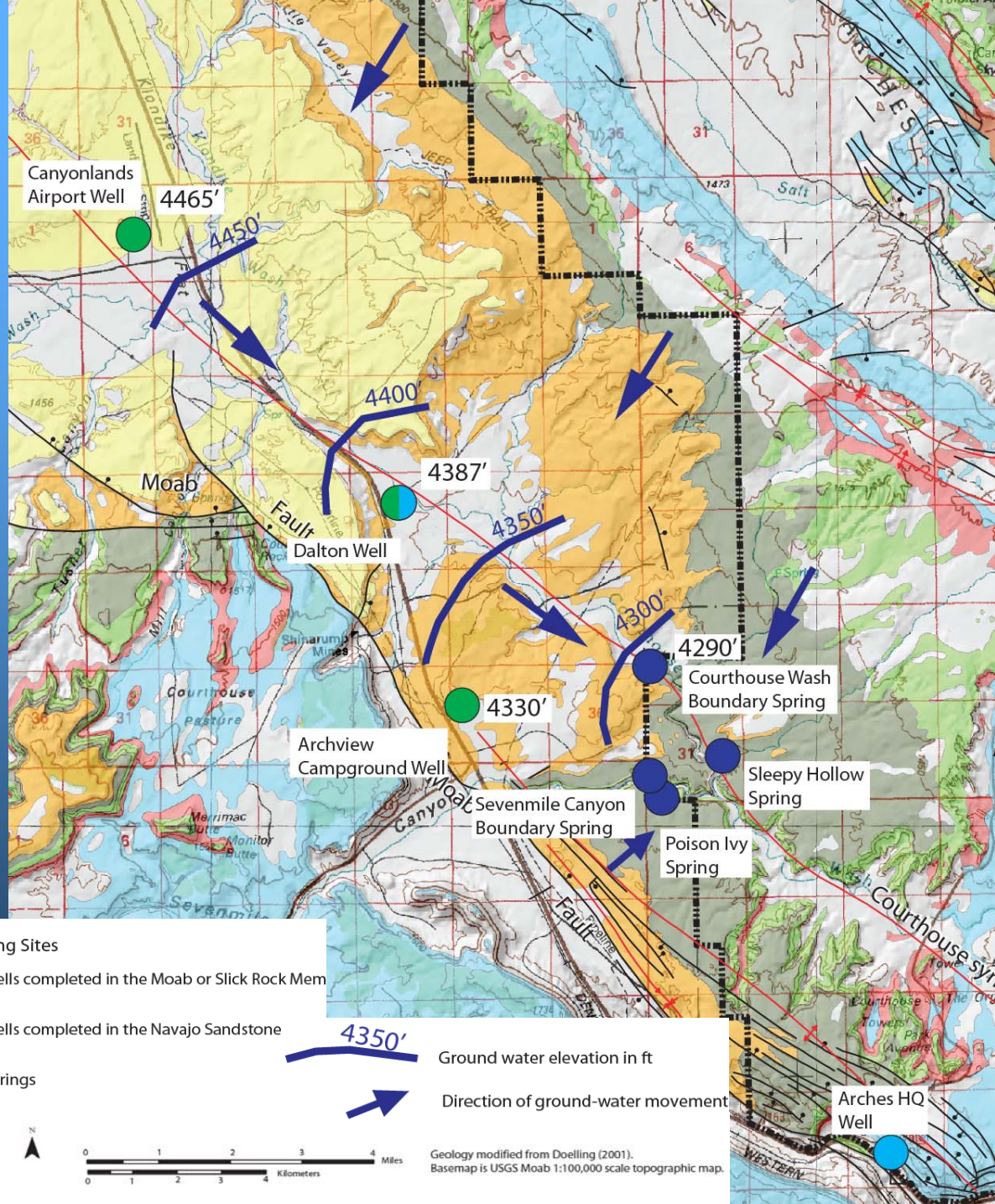
Hydrogeology

- Jurassic units
- Gently folded in hanging wall of Moab Fault
- Moab Member exists in both unconfined and confined settings
- Geographic isolation
- Structural control?



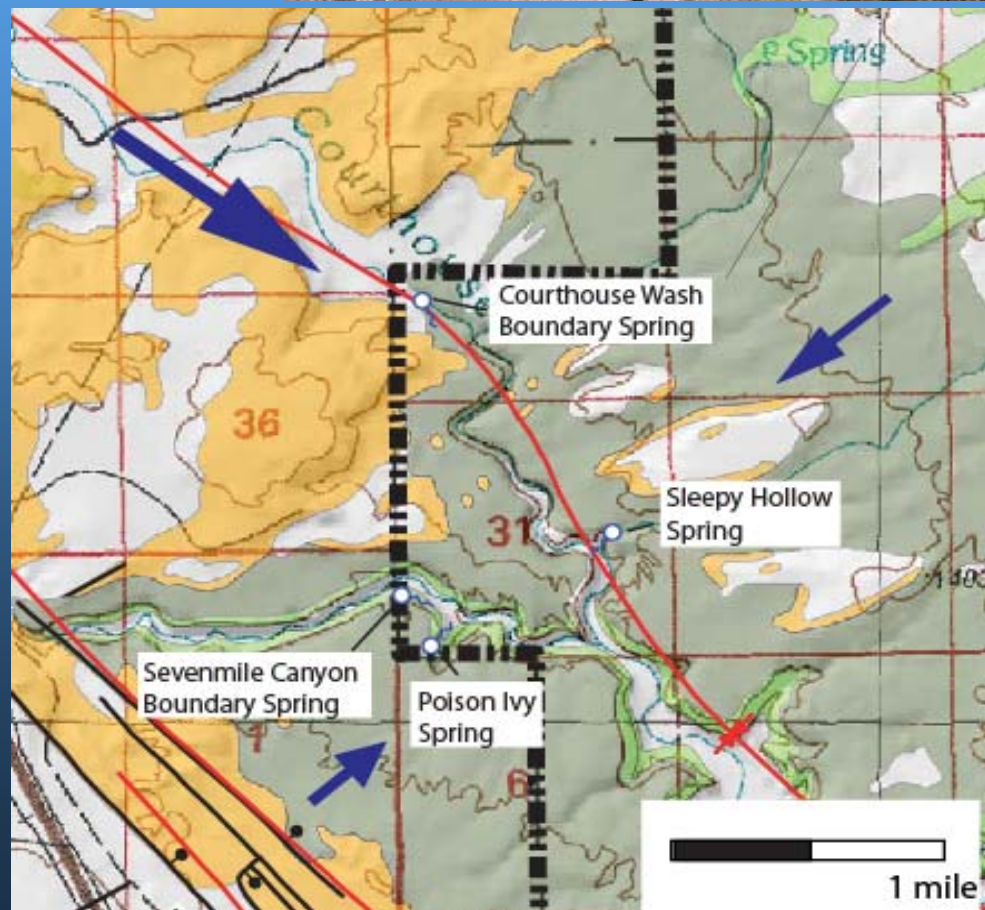
Hydrogeology

- Assumed regional GW flow to E and or SE (CO River) (Hurlow and Bishop, 2003; Rush and others, 1982)
- Local GW flow more complex
- Structural control
- Geographic control



Spring hydrogeology

- 3 springs issue from the base of Moab Member on limbs of CHS
- CHWBS issues from near the top of Moab Member and contact w/ alluvium (confined?)
- Flow Rates between 13 and 1 GPM (NPS)

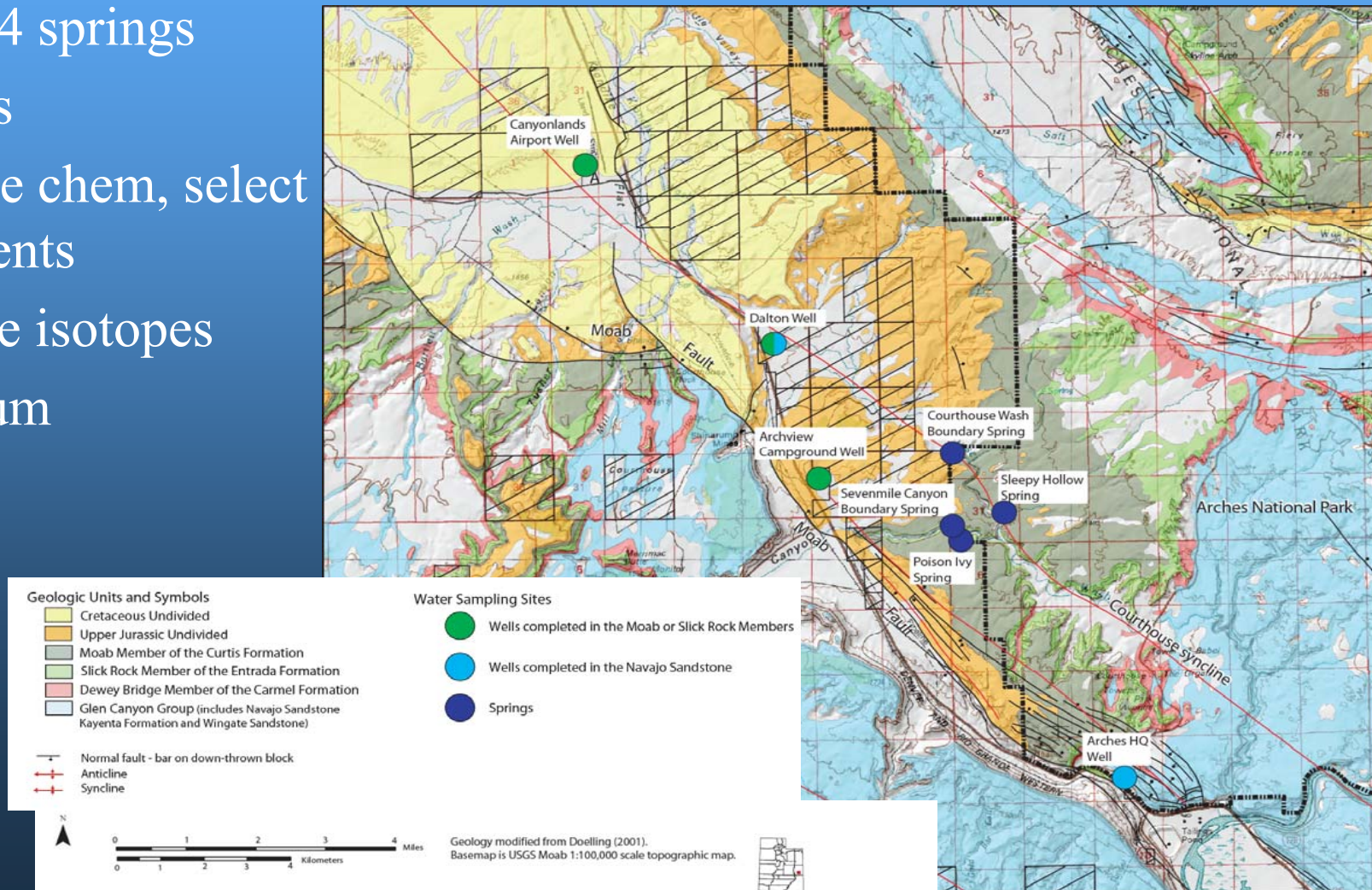


Well hydrogeology

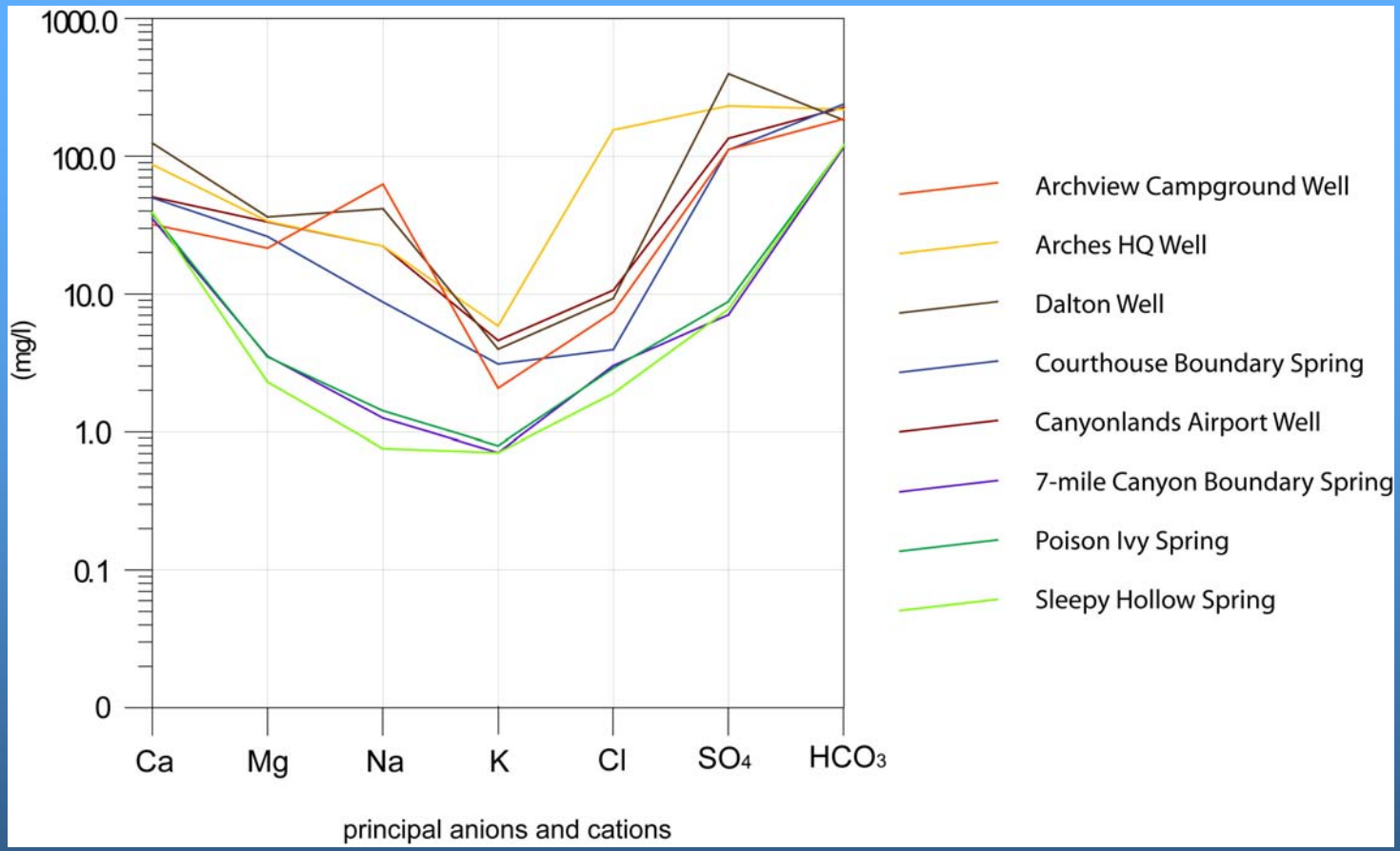
- Confined and unconfined
- Wells completed in Moab/Slick Rock Members (Archview and Canyonlands Airport)
- Dalton Well completed in Moab/Slick Rock Members and Navajo SS?
- Arches HQ well completed in Navajo SS

Sampling

- Funded by the NPS WRD
- 4 wells, 4 springs
- Analyses
  - Solute chem, select nutrients
  - Stable isotopes
  - Tritium
  - C14

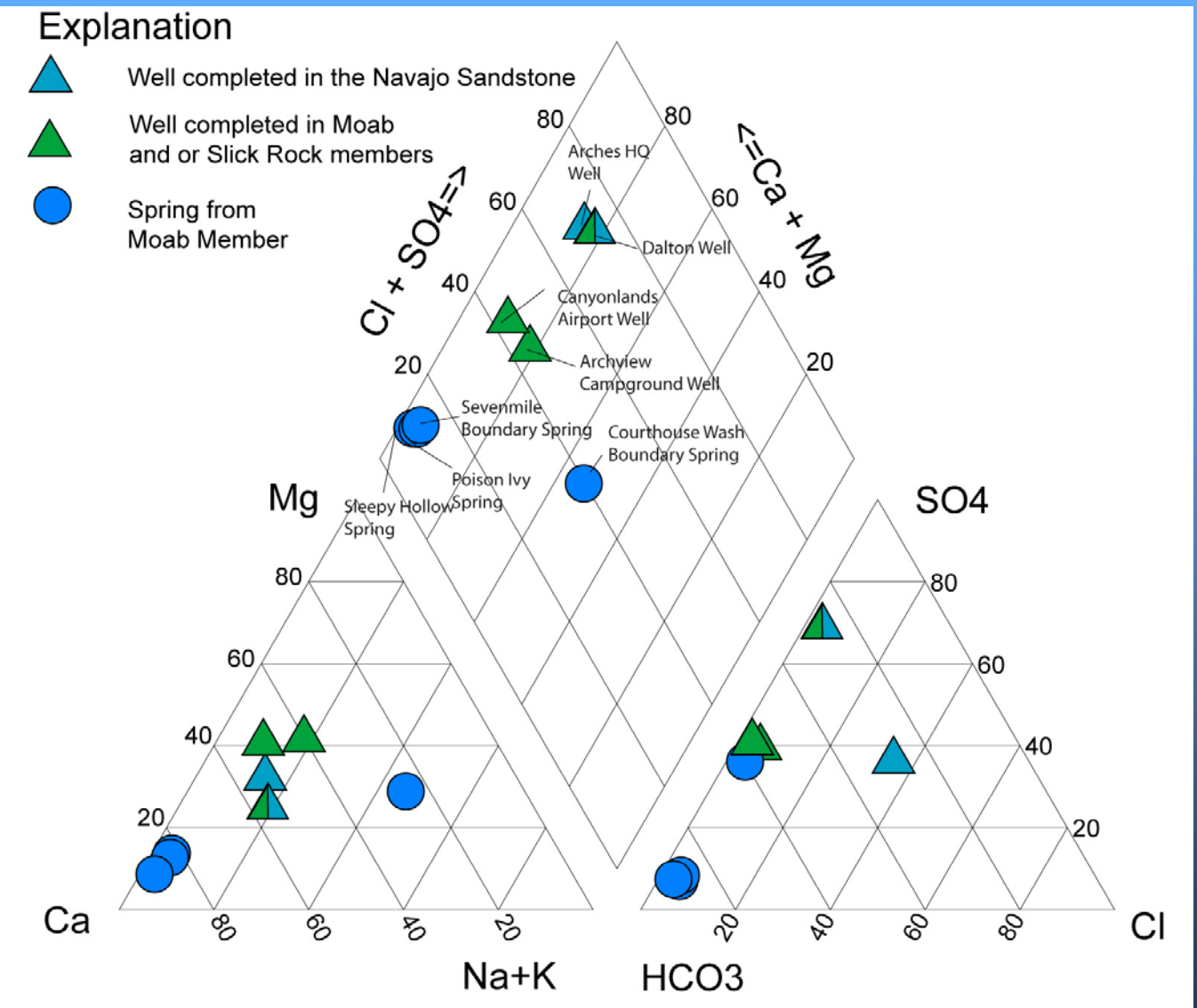


Solute Results



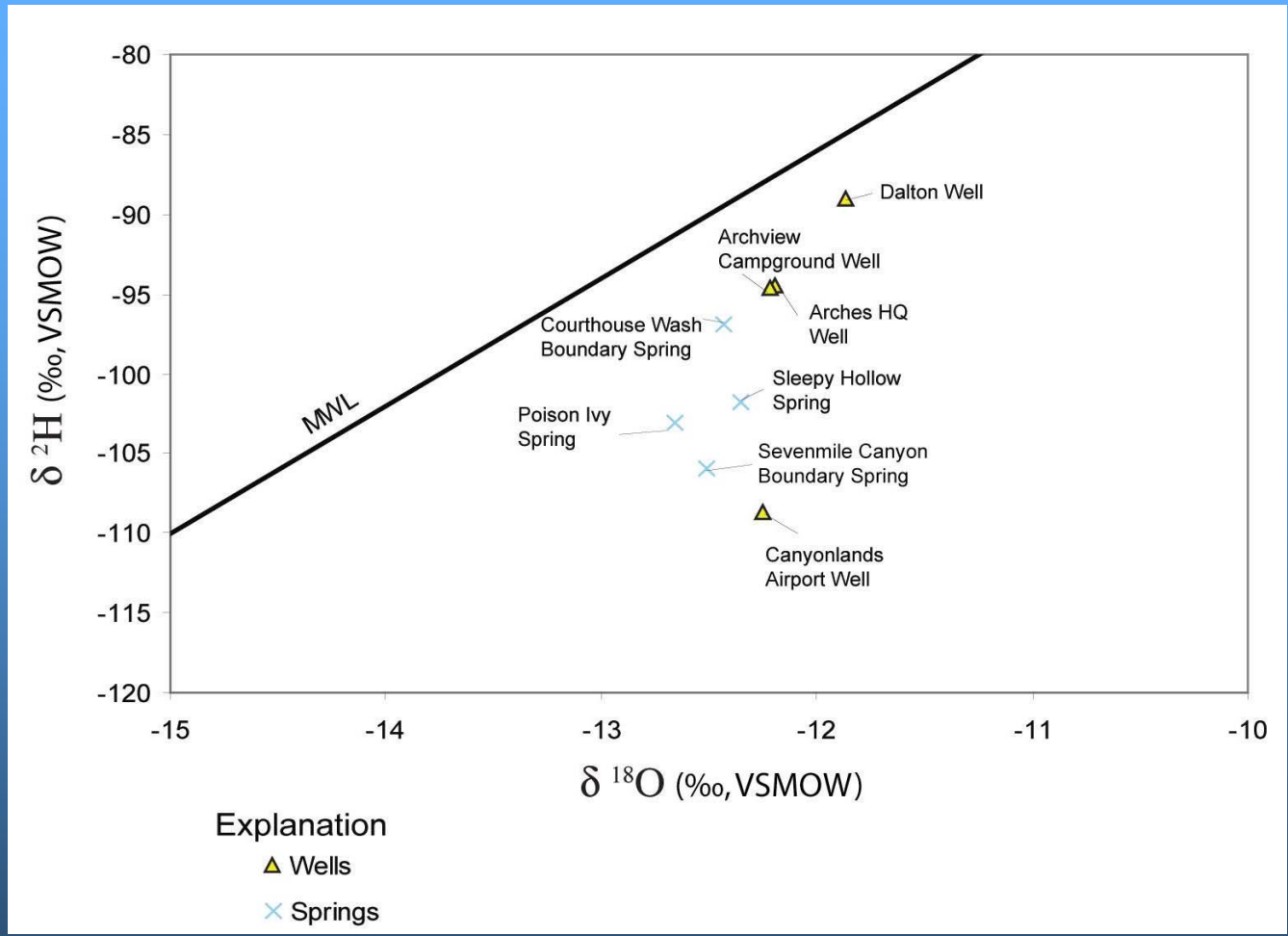
- Water types include Ca-HCO3 to Na or Mg, Ca-HCO3 and sulfate
- Relation among springs, wells?
- Mineral saturations

Piper Diagram



- Spring cluster
- Wells (unit completed in)

Stable Isotope Results



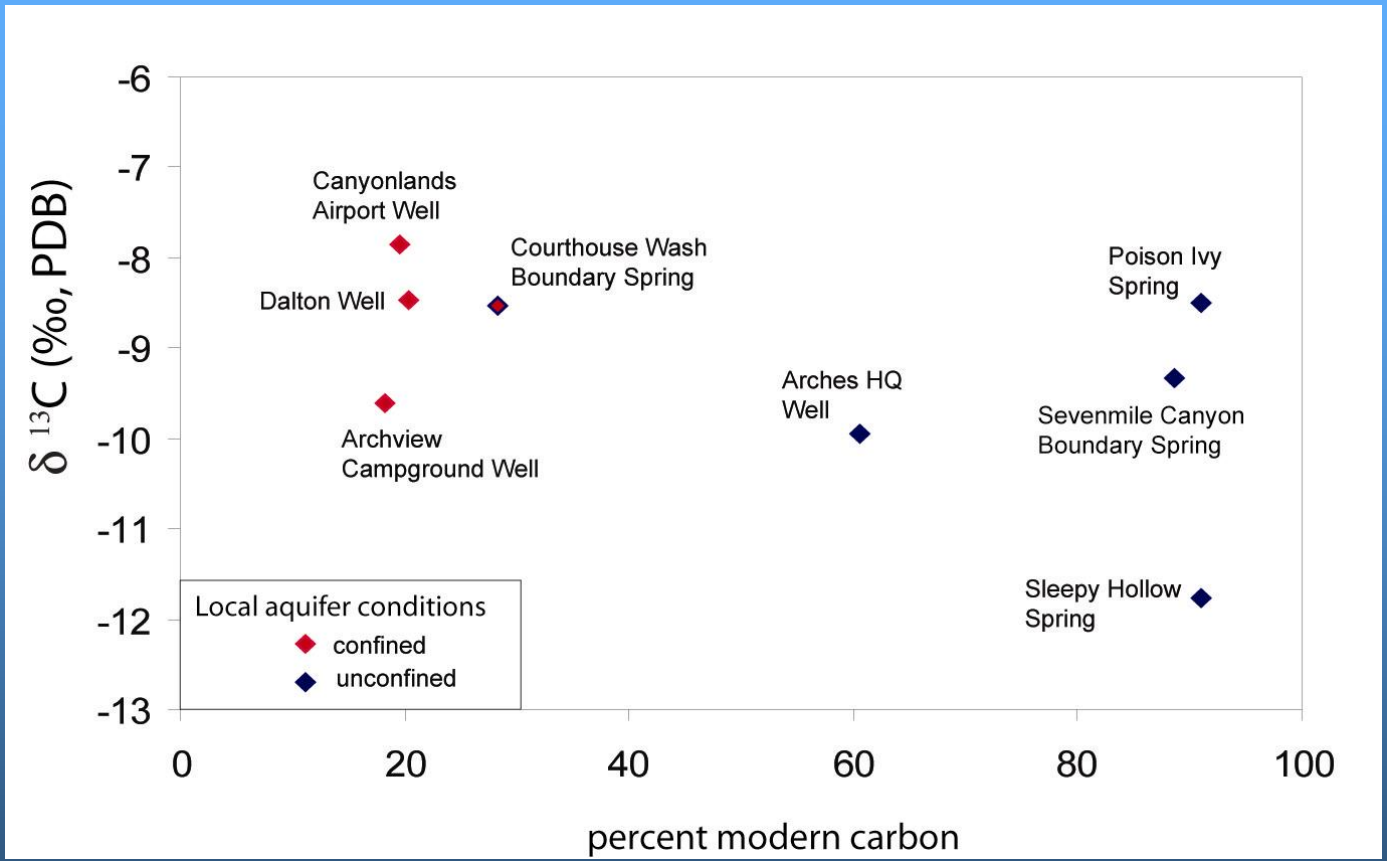
- Unconfined springs depleted relative to others
- Evaporative enrichment and or mixing, or different source of recharge for confined sites?
- Similarity of springs but still different sources of recharge

Tritium Results

Site	TU	Error
Archview Campground	0.6	0.2
Arches HQ Well	2.0	0.2
Dalton Well	2.3	0.6
Courthouse Boundary Spring	0.3	0.3
Canyonlands Airport Well	9.7	0.3
7-mile Boundary Spring	ND	0.4
Poison Ivy Spring	6.3	0.6
Sleepy Hollow Spring	1.3	0.2

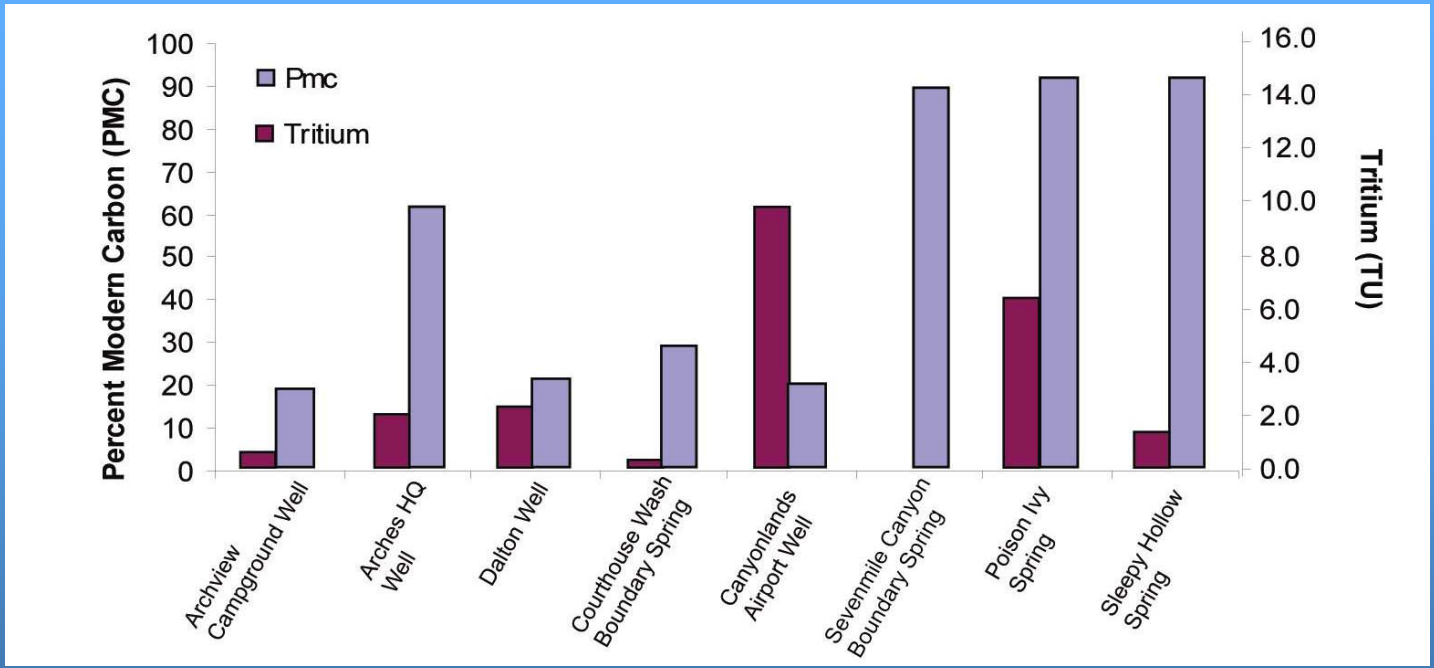
- Analyzed by enrichment and scintillation counting at BYU
- Ranges from ND to 9.7 TU, error 0.2 to 0.6
- Sites with values > 2.0 TU contain at least a component of modern water (<1950)

Carbon Isotope Results



- Analyzed via AMS methods at CAIS at UGA
- PMC (percent modern ^{14}C) values range from 18 to 91
- $\delta\ ^{13}C$ range from –8.5 to –11.7 ‰
- Error plus/minus 0.5 ‰ for $\delta\ ^{13}C$ and 0.16 to 0.47 for pmc

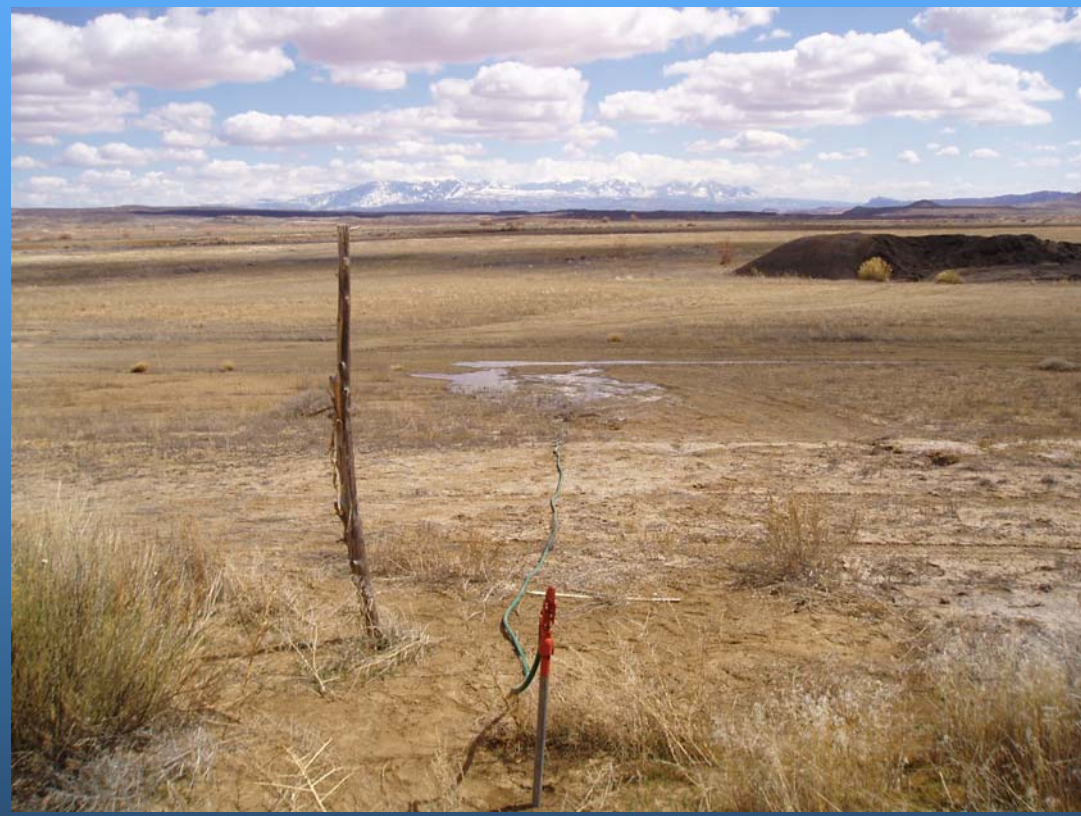
C Isotope and Tritium



- Pmc > 60% and tritium > 2.0 TU occurs in sites Arches HQ and Poison Ivy Spring (modern)
- High pmc and low tritium < 2.0 Sevenmile Canyon and Sleepy Hollow Spring (nearly modern)
- Pmc < 60% = component of old water at Archview Campground, Dalton Well, Canyonlands Airport, and Courthouse Wash Boundary (also component of younger recharge)

Implications and Discussion

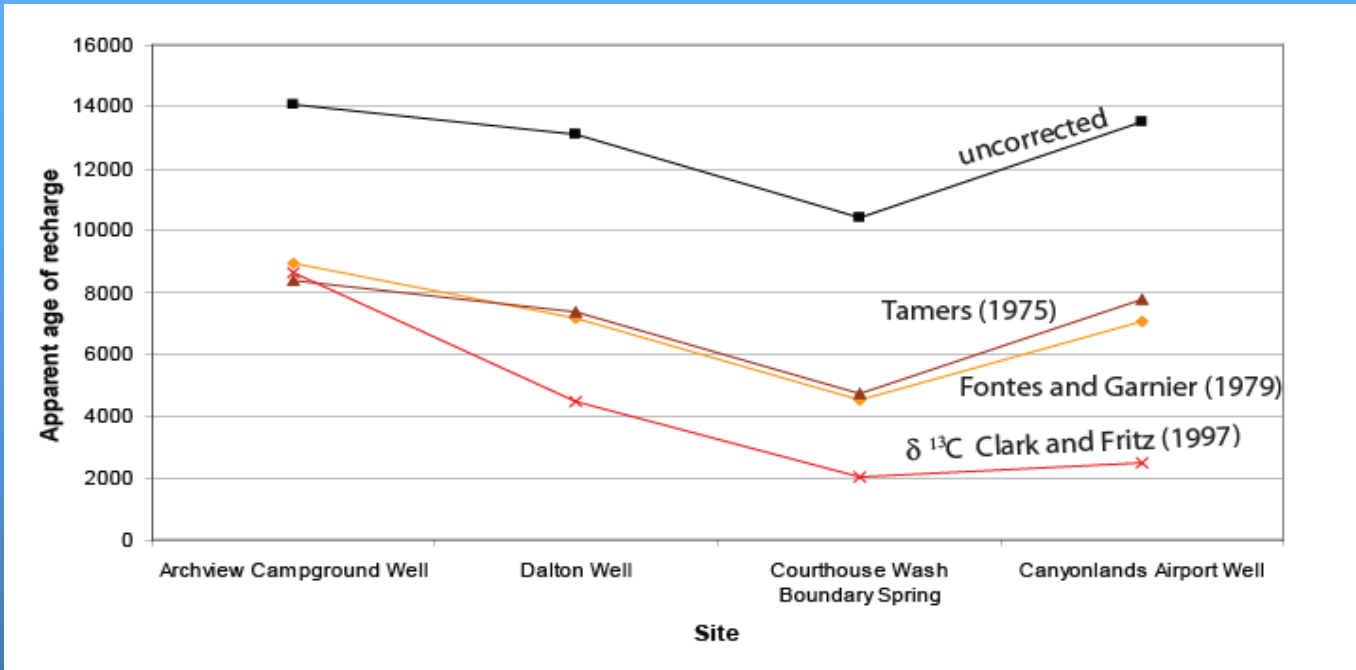
- Wells w/ young and old?
- Geologic control
- Modern recharge geologically unlikely at several sites (Airport, Dalton, Archview)
- Well completions?
- Young and low tritium?
- ‘premodern’ recharged prior to 1950 but not old
- CHWBS lack of modern water geologically unlikely



Qualitative age summary

- Arches HQ well modern
- 3 springs modern or very nearly modern
- Wells mix of old and young
- CHWBS old and ‘just premodern water’?
- Quantitative estimates of residence time?

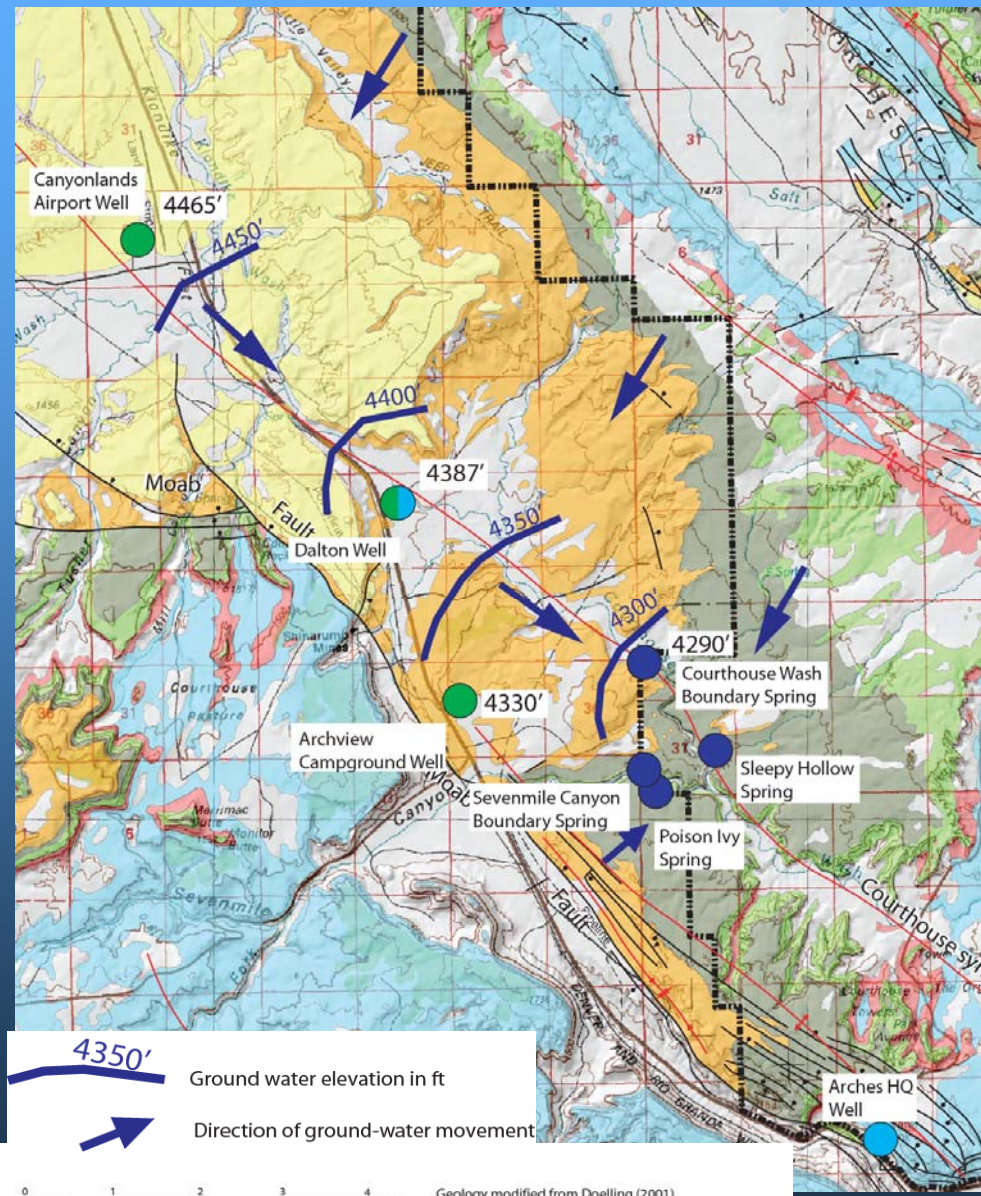
Simple age corrections



- Quantitative age estimates based on observed ^{14}C concentration and assumptions/models of initial ^{14}C and decay equation
- Assume ^{14}C soil = 100 pmc, carbonate- mineral ^{14}C = 0 pmc, $\delta^{13}C$ soil gas = −20‰, carbonate-mineral $\delta^{13}C$ = -6‰ Chan and others (2000) and Gardner and others (2001)
- Tamers (1975) closed system
- Fontes and Garnier (1979) isotopic mixing and exchange
- Clark and Fritz (1997) modified from Pearson (1965) (end member)
- Can we do better?

NETPATH

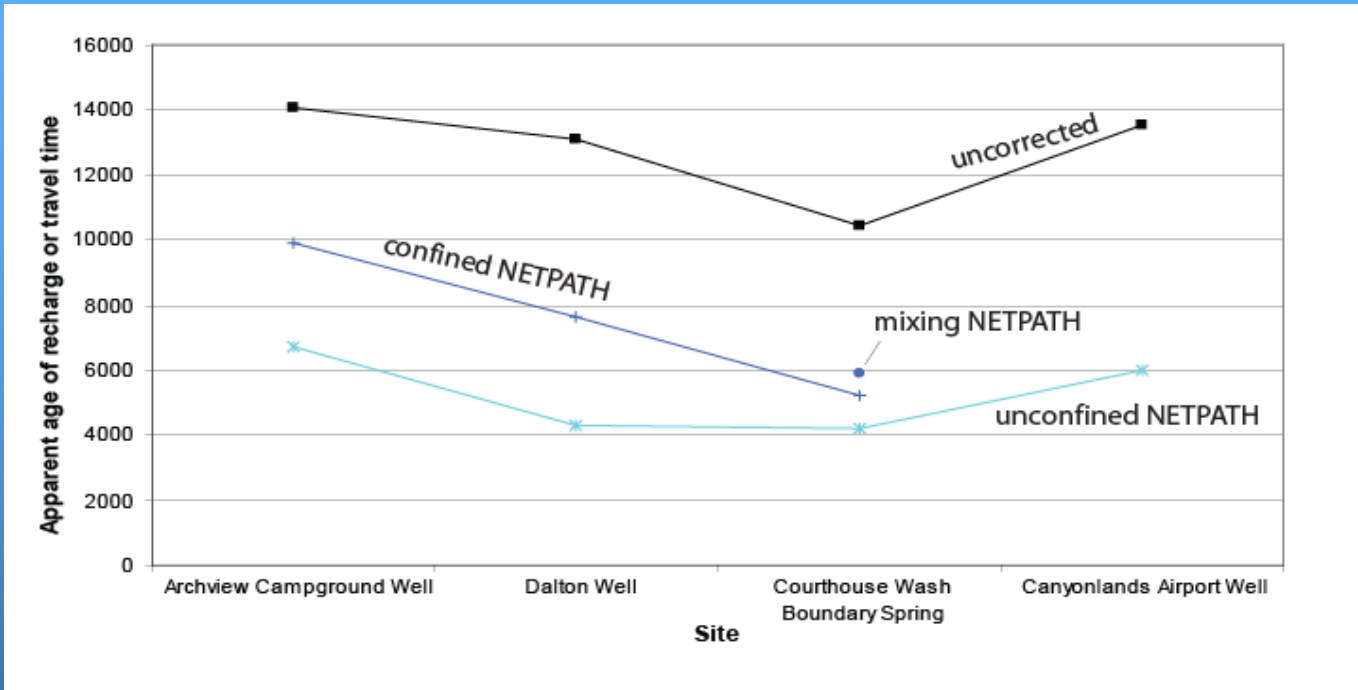
- NETPATH (Plummer and others, 1994) inverse modeling and carbon mass balance.
- Balance mineral phase reactions along flow paths
- Initial and final sampling points
- Water from Canyonlands Airport well could reach other low PMC sites
- Water from unconfined Moab Member
- Assume Poison Ivy or Canyonlands Airport as initial sites
- Mixing of waters



NETPATH model background

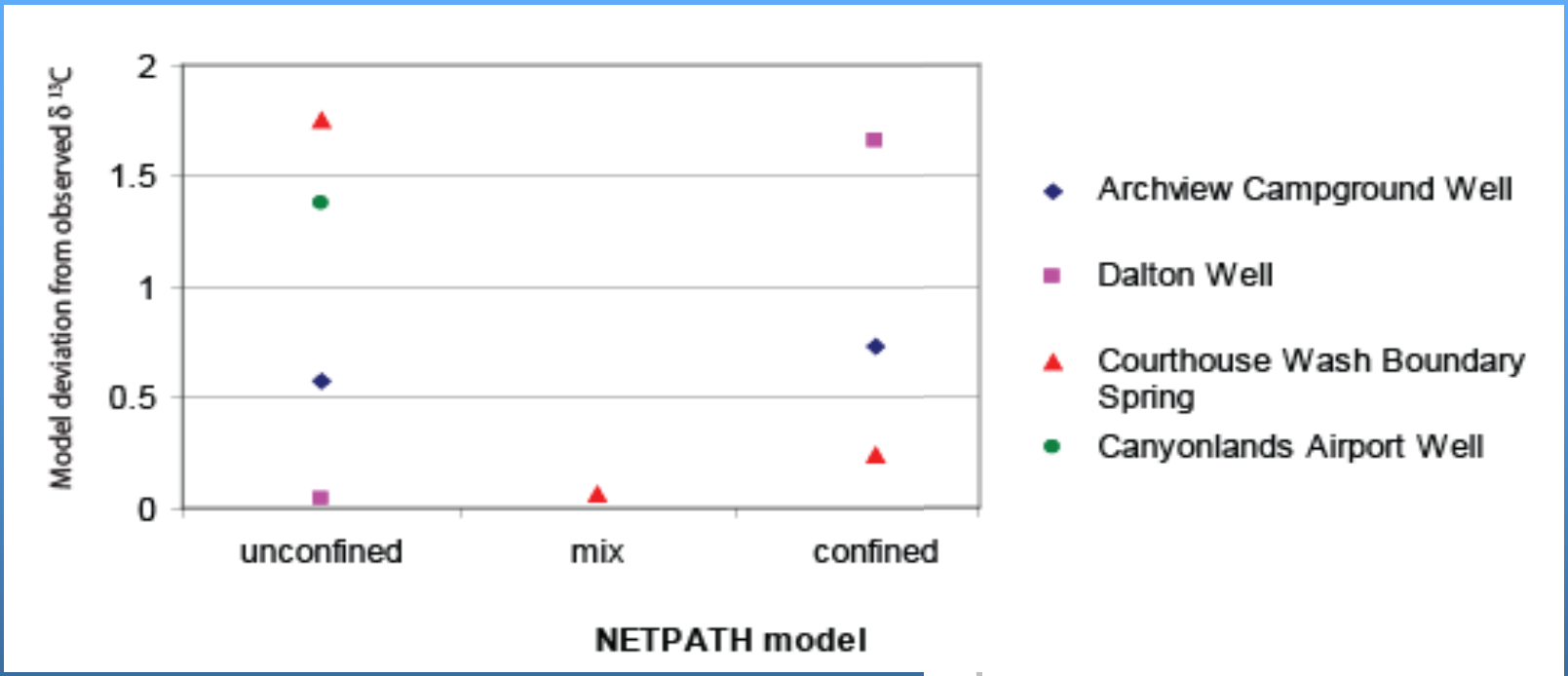
- Initial water assumed to be similar to Poison Ivy Spring and or Canyonlands Airport well
- Available mineral phases and $\delta\ ^{13}C$ (-6 ‰, PDB) of calcite cements taken from Chan and others (2000), Garden and others (2001), and background geology Doelling (2001), Doelling and Morgan (2000)
- Phases include: Calcite, Dolomite, CO2 gas, Gypsum, Ca/Na Exchange, Halite, Illite
- Constraints include: C, Ca, Mg, Na, K, Cl, S
- Final model chosen based on fit of computed $\delta\ ^{13}C$ with observed data

NETPATH models



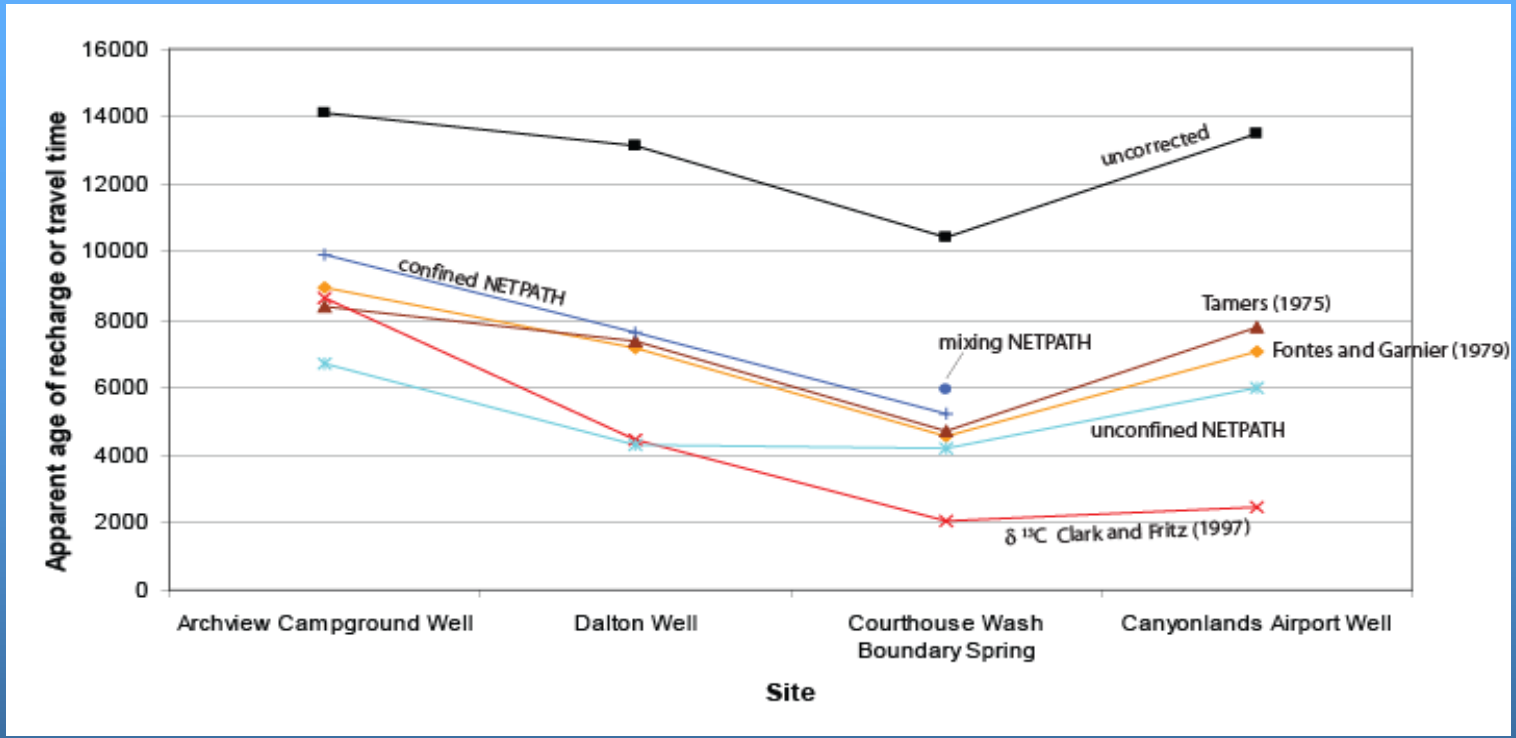
- Most models show minor calcite precip with dissolution of other phases
- Unconfined ages (initial is Poison Ivy Spring)
- Confined NETPATH 'ages' are travel time from initial well (initial is Canyonlands Airport)
- Travel time of Dalton Well vs CHWBS?? (effect of Jn component)
- Mix is 80 Canyonlands Airport and 20 Poison Ivy Spring

Model fit



- Comparison of model computed δ ^{13}C with observed value
- 0.5 is approximate error range of δ ^{13}C observed
- Best fit for CHWBS is mix

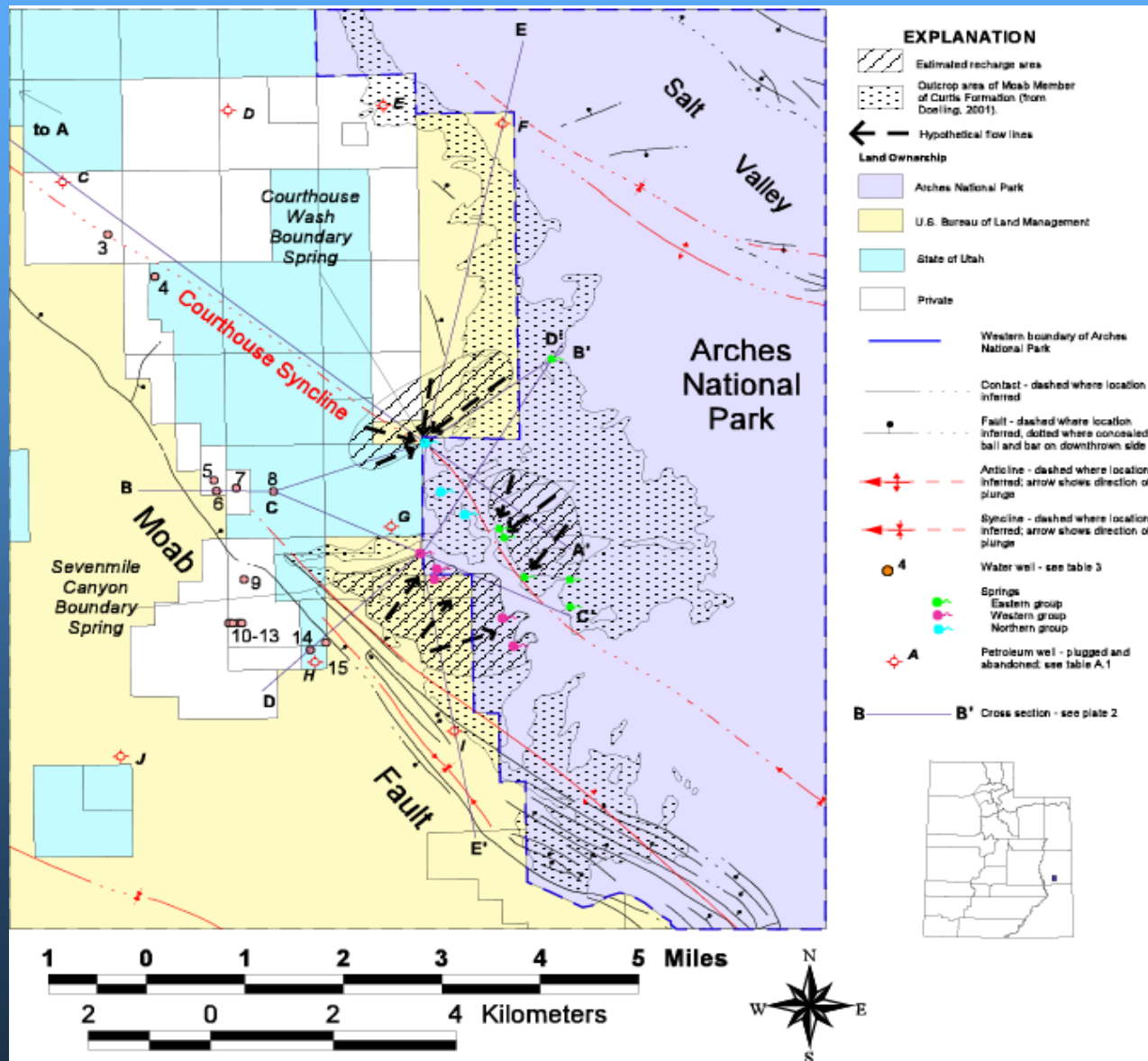
Age Summary



- By nearly any measure CHWBS has water recharged > several 1000 years ago (most solutions 4000-6000)
- Other low pmc wells are likely older
- Error is potentially LARGE
- Not unique solutions

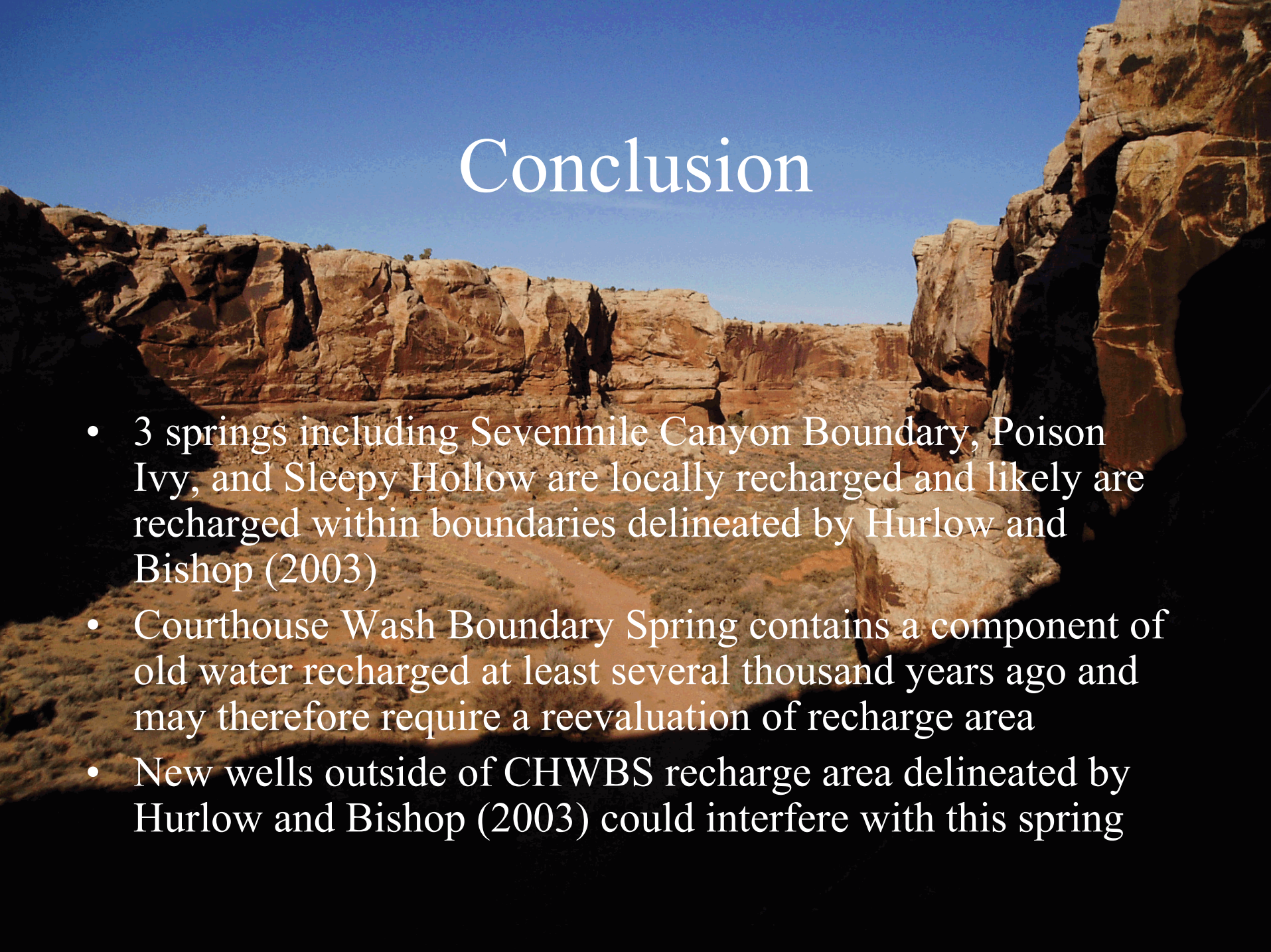
Previous Recharge Areas

- Hurlow and Bishop (2003)
- Assumptions
  - Mostly modern water
- Works for 3 springs including 7-mile, Poison Ivy, and Sleepy Hollow



Recharge area CHWBS

- Previously based on a significant component of modern recharge
- Old water however (with smaller component of younger water)
- Could include water similar to that from Canyonlands Airport and water from unconfined portions Moab Member
- Lower recharge rates, and or longer travel time, larger recharge area?



Conclusion

- 3 springs including Sevenmile Canyon Boundary, Poison Ivy, and Sleepy Hollow are locally recharged and likely are recharged within boundaries delineated by Hurlow and Bishop (2003)
- Courthouse Wash Boundary Spring contains a component of old water recharged at least several thousand years ago and may therefore require a reevaluation of recharge area
- New wells outside of CHWBS recharge area delineated by Hurlow and Bishop (2003) could interfere with this spring

Further Work

- Should focus on flow paths to CHWBS
- Additional hydrogeological data… ie potentiometric surface?… additional sampling, dissolved gas work (if possible)
- Numerical modeling of CHWBS flow system